REMARKS

Claims 1-13, 16, 34, 36-38, and 55-60 are pending in the application, claims 39-54 having been canceled herein without prejudice or disclaimer, and claims 14, 15, 17-33, and 35 having been previously cancelled. The Examiner has previously indicated that claims 1-13, 16, 34, 36-38 are allowed.

The Invention

The present invention advantageously allows the size of the bond site along the catheter to be reduced relative to the size of the bond site that would result if a non-annular beam were used. This feature of the invention can be understood with reference to figures 1 and 2 below, which both employ a non-annular beam (for purposes of clarity, no rays are shown that directly impinge upon the catheter, although such rays would of course be present). The diameter of the catheter in FIG. 2 is shown to be twice the diameter of the catheter in figure 1. In figure 1, the bond site extends over an axial distance L and in figure 2 the bond site extends over an axial distance L′. As the figures indicate, the distance L increases as the catheter diameter increases. This is because as the catheter diameter increases, the bond site becomes more and more displaced from the focal point of the mirror, allowing light rays with a greater range of incident angles to impinge at different points along the catheter. Thus, the size of the bond site is to a large extent dependent on the diameter of the particular catheter being sealed, thereby making it difficult to control the length of the bond site size.

On the other hand, when an annular beam is employed, the size of the bond site can be reduced by eliminating the centermost rays that strike the catheter at the larger angles of incidence. It is these rays (e.g. rays 0 and 1 in figure 2) that cause the increase in the bond site size. FIG. 3 shows the use of an annular beam in accordance with the present invention. The catheter in figure 3 is depicted as having the same diameter as in Figure 2. The axial bond site size L′ in figure 3 is clearly much less than the axial bond site size L" in figure 2. As figure 2 suggests, the size of the bond site is largely independent of the catheter diameter.

The Rejection

In the Office Action claims 55-60 were rejected under 35 U.S.C. 103(a) as being unpatentable over Forman in view of Wysocki et al. This rejection is hereby traversed for the following reasons.

At the outset, it should be noted that in removing the prior rejection of claim 55 under 35 U.S.C. 102 in the Office Action, the Examiner apparently recognizes that Forman does not disclose the combination of generating an annular beam of electromagnetic energy such that the annular beam is disposed about the longitudinal axis of the polymeric catheter tube without impinging on the polymeric material or the polymeric catheter tube and controllably redirecting at least a portion of the annular beam such that it converges on the polymeric material at the over-lapped portion circumscribing at least a portion of the polymeric catheter tube.

The Examiner asserts, however, that the aforementioned claimed features of the invention are set forth in Wysocki et al.

Wysocki et al.

The Examiner asserts that Wysocki et al. discloses the use of an annular beam to fusion-weld a pair of optical fibers. More specifically, the Examiner asserts that the beam produced by the beam expander 30 in figure 2 of the patent generates an annular beam. Applicant respectfully disagrees. As is well known to those of ordinary skill in the art, a beam expander simply increases the diameter of a light beam. The expanded beam is generally coaxial with respect to the initial beam. More significantly, the expanded beam also has an energy distribution across its diameter that is equal to the energy distribution across the diameter of the original beam that has been spatially expanded. Enclosed herewith is a description of a beam expander as set forth in Pedrotti, F.L. and Pedrotti, L.S. *Introduction to Optics*, 2nd Ed. Englewood Cliffs: Prentice-Hall, Inc., 1993, Ch. 21. In particular, figure 21-20 on page 450 of the reference shows that the beam expander simply comprises two lenses; there is no component present to convert the incident beam into an annular beam.

In the Office Action the Examiner questions how a redirected beam can effectively uniformly heat optical fibers around their whole circumference if the laser beam is not annular. This can be understood with reference once again to figures 1 and 2. The redirected beam encompasses the whole circumference of the fiber or catheter because the mirror is a three-dimensional paraboloid, not because the beam is annular. Of course, the figures only show a single cross-section through the three-dimensional mirror.

While the non-annular beam employed by Wysocki et al. does in fact generate a uniform circumferential beam, it does not allow the axial size of the bond site to be controlled to a large extent independent of the fiber diameter. Only the present invention achieves this advantage by using an annular beam. This feature of the invention is set forth in claim 55 by reciting, inter alia, *an annular beam ... disposed about the longitudinal axis of the polymeric catheter tube without impinging on the polymeric material or the polymeric catheter tube.* That is, the central-most rays (e.g., rays 0 and 1 in figures 1-3) are removed. As further recited in claim 55, it is the redirected portion of the annular beam that converges on the polymeric material. By contrast, in Wysocki et al., both the original beam and the redirected portion of the beam impinge on the fiber.

Conclusion

In view of the foregoing, it is believed that Claims 1-13, 16, 34, 36-38, and 55-60 are now in condition for allowance and early passage of this case to issue is respectfully requested. If the Examiner believes there are still unresolved issues, a telephone call to the undersigned would be welcomed.

Fees

The Examiner is authorized to charge all fees due and owing in respect to this amendment to deposit account number 50-1047. An Amendment Transmittal letter is filed herewith.

Power of Attorney

A Power of Attorney And Revocation of Previous Power is filed herewith. Please direct all future correspondence to the undersigned new attorney of record.

Patent: 09/654,987

Respectfully submitted,

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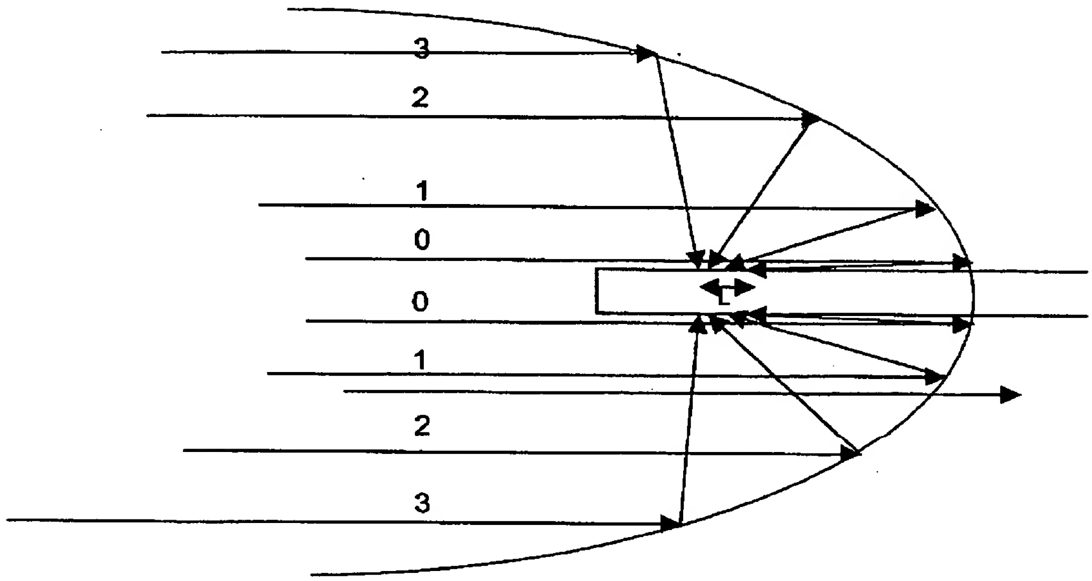


Figure 1

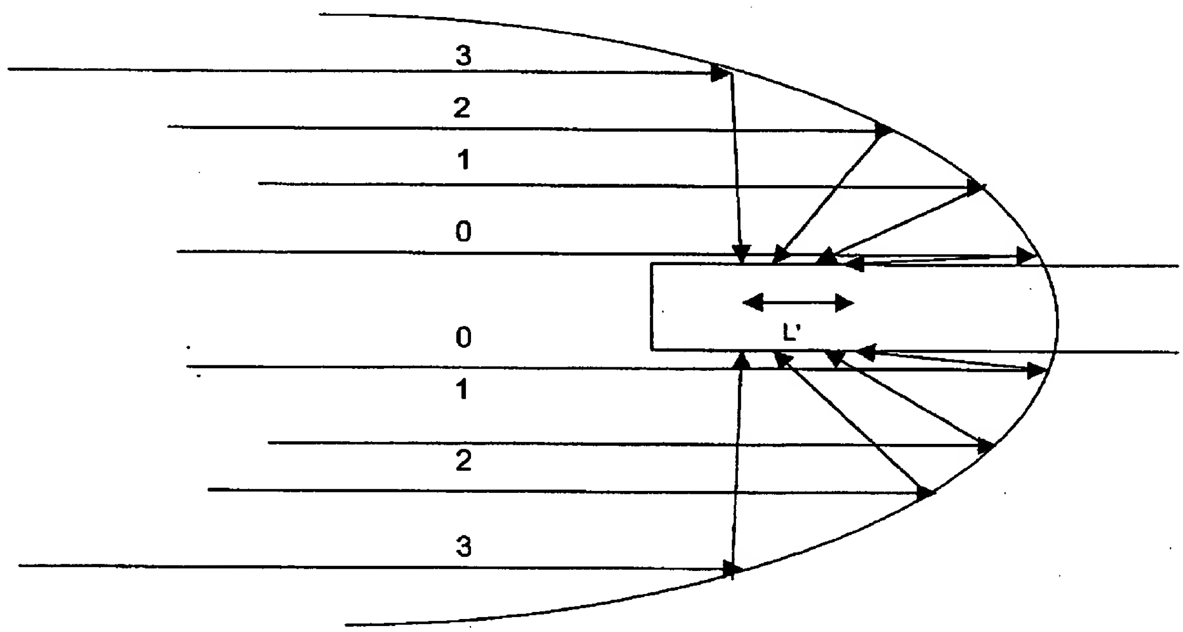


Figure 2

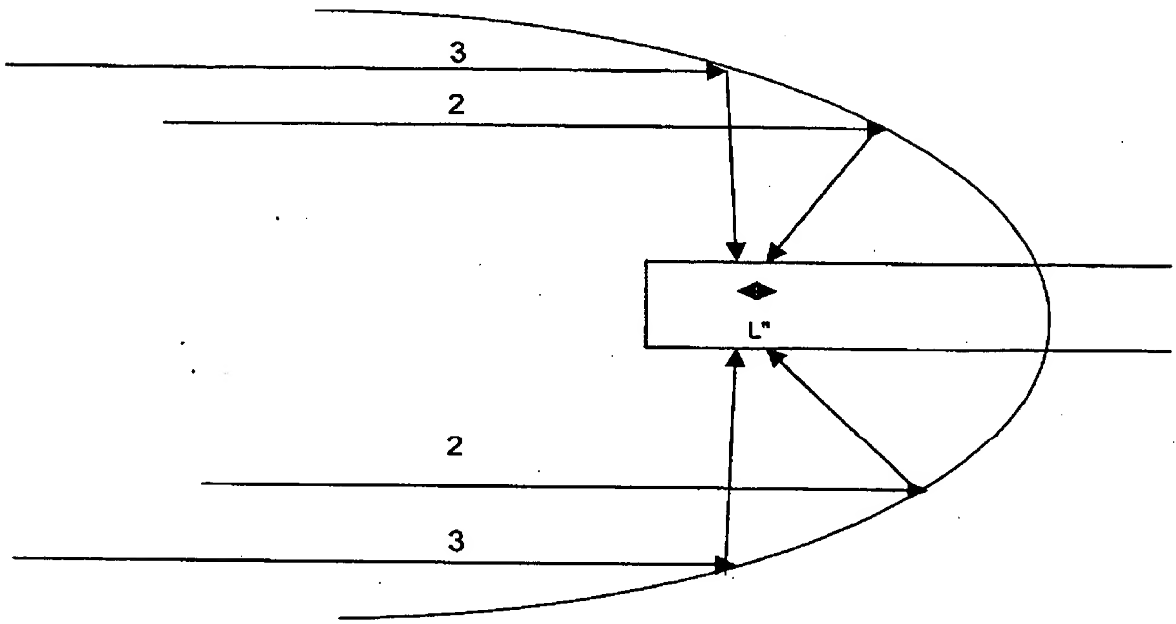
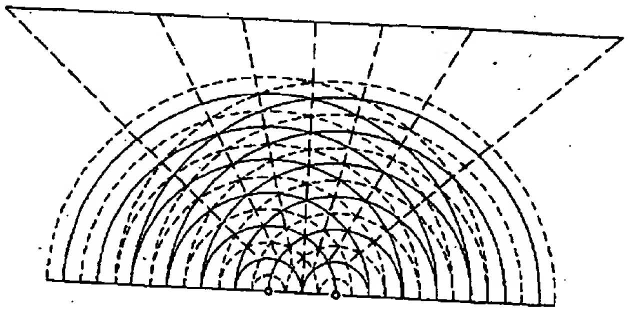


Figure 3



Second Edition

Introduction to Optics

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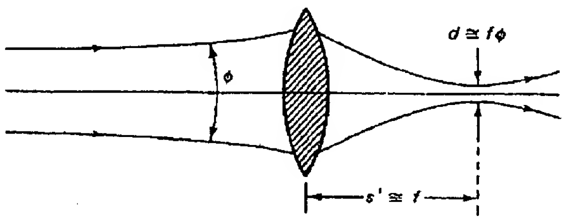

Figure 21-19 TEM$_{00}$ laser beam of beam spread angle ϕ.

in Eq. (21-13) refers to the diameter of the laser beam focused by the positive lens. The location of the focused laser spot is essentially at the focal plane of the lens ($s' = f$), although a careful analysis shows that this is, in fact, an approximation, even if a good one.

With the help of Eq. (21-13), we can make several rough calculations to predict the spot size of focused laser beams. With a lens of focal length $f = 0.1$ m and incident laser light of beam divergence $\phi = 10^{-3}$ to 10^{-4} rad, spot sizes of the order of 10^{-4} m to 10^{-5} m (or 100 μm to 10 μm) in diameter can be obtained easily. If we compare these diameters with the wavelength of the carbon dioxide laser (λ = 10 μm), we see at once that CO_2 laser light—indeed all laser light—can be focused to spot sizes of the order of a wavelength.

Equation (21-13) indicates that focusing laser light down to small spots can be achieved by lenses with short focal lengths and laser beams with small beam divergences. As long as aberration-free lenses of high quality are available, the focal length can be chosen as short as is practical. The beam divergence of a laser, usually determined at the time the laser is designed, can still be reduced with the additional optics found in *beam expanders*. In Figure 21-20, a collimated laser beam of width W_i and beam divergence ϕ_i is focused by the first lens of the beam expander (focal length f_1) to a spot of diameter $d = f_1\phi_i$, in accordance with Eq. (21-13). The second lens, a distance f_2 from the focused spot, with $f_2 > f_1$, collects the light expanding from the focused spot and essentially recollimates it. The beam divergence of the expanded, recollimated beam is equal to

$$\phi_f = \left(\frac{W_i}{W_f}\right)\phi_i = \left(\frac{f_1}{f_2}\right)\phi_i \qquad (21\text{-}14)$$

where $f_2/f_1 = W_f/W_i$ is the *beam expansion ratio*. The validity of Eq. (21-14) is not difficult to show. The incident beam, focused by the first lens, has a spot diameter $d_1 = f_1\phi_i$. By the principle of reversibility of light, if the expanded beam were to be

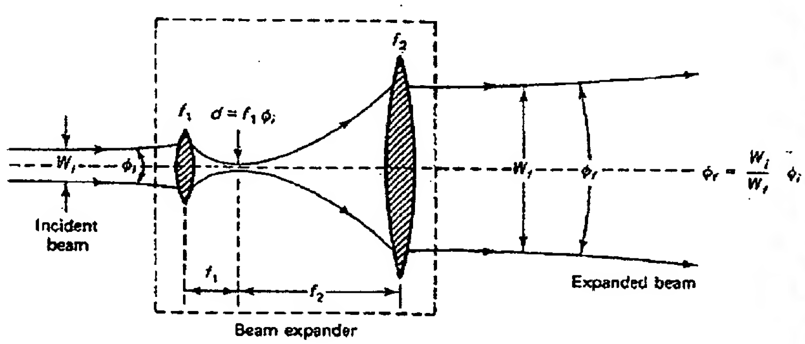

Figure 21-20 Beam expansion as a method of reducing beam divergence of a laser beam.

redirected to the left and focused by the second lens, it would form the identical spot at the same location, so that $d_2 = f_2\phi_f$. Since $d_1 = d_2$ necessarily,

$$f_1\phi_i = f_2\phi_f$$

$$\phi_f = \frac{f_1}{f_2}\phi_i$$

If the beam expansion ratio is $f_2/f_1 = 5$, the beam divergence of the expanded laser beam is $\frac{1}{5}$ that of the incident beam. Expanding the beam width by a factor of 5 achieves a reduction in beam divergence by the same factor.

What has been gained? Suppose a laser beam is expanded 10-fold by an appropriate beam expander. The outgoing beam then has had its beam divergence decreased by a factor of 10. If the expanded beam is then focused to a tiny spot with a lens of arbitrary focal length f, the diameter of the spot will be $\frac{1}{10}$ that achievable with the unexpanded beam and the same lens. This 10-fold reduction in diameter leads to a 100-fold reduction in spot size area and thus, for any given laser beam power, to a 100-fold increase in focused spot irradiance.

Laser energy focused onto small target areas makes it possible to drill tiny holes in hard, dense material, make tiny cuts or welds, make high-density recordings, and generally carry out industrial or medical procedures in target areas only a wavelength or two in size. In ophthalmology, for example, where Nd:YAG lasers are used in ocular surgery, target irradiances of 10^9 to 10^{12} W/cm^2 are required. Such irradiance levels are readily developed with the help of beam expanders and suitable focusing optics, as was discussed in Section 7-5 (see problem 7-10).

21-5 LASER TYPES AND PARAMETERS

To this point we have examined the basic assumptions that led Einstein to predict the existence of stimulated emission, identified the essential parts that make up a laser, described in a general way how a laser operates, and studied the characteristics that make lasers such a unique source of light. Now, by way of summary, we turn our attention to the identification of some of the common lasers in existence today and to parameters that distinguish them from one another.

Lasers are classified in many ways. Sometimes they are grouped according to the state of matter represented by the laser medium: gas, liquid, or solid. Sometimes they are classified according to how they are pumped: flashlamp, electrical discharge, chemical actions, and so on. Still other classifications divide them according to the nature of their output [pulsed or continuous wave (cw)] and according to their spectral region of emission (infrared, visible, or ultraviolet).

No particular classification scheme has been chosen for the lasers listed in Table 21-2. Those identified are, in a way, a cross section of the 30 or 40 common lasers on the market today. A careful examination of Table 21-2 serves as an introduction to the state of laser technology. For each laser listed, the entries include data on emission wavelength, output power (or in some cases, energy per pulse), nature of output, beam diameter, beam divergence, and operating efficiency. Table 21-2 includes examples of gas lasers (He-Ne, CO_2, nitrogen); solid state lasers (ruby, Nd:YAG, Nd-glass); liquid or dye lasers; semiconductor lasers (gallium arsenide); the excimer gas lasers (argon fluoride); chemical lasers (hydrogen fluoride); and ion lasers (argon ion). Both pulsed and continuously operating (cw) lasers are represented. Taken as a wh le, Table 21-2 includes lasers whose wavelengths vary from 193 nm (deep ultraviolet) to 10.6 μm (far infrared); whose cw power outputs vary